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ARRANGEMENTS OF PULSE QUADRUPOLES IN THE MAIN RING FOR γ_t-JUMP

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As computed in FN-215 and FN-215A the transition energy (γ_t) jump in the main ring necessary at full intensity (5×10^{13} ppp) to match beam bunch length across transition is in the range

$$|\Delta\gamma_t| \approx 0.25 - 1.12.$$

As shown in FN-207, to produce this γ_t-jump without sensibly affecting ν_x and ν_y one needs a quadrupole arrangement around the ring which gives a field gradient having a zero average and a large 20th harmonic (integer closest to ν_x). The quadrupoles should therefore be in fd pairs separated by about $\frac{1}{40}$ of the circumference. For $n < \nu_x < n+\frac{1}{2}$ (n = integer) the f quadrupole will decrease the local value of the dispersion function x_p and the d quadrupole will increase the local value of x_p. The difference between the two values of x_p gives the increase of the average x_p, hence the decrease in γ_t. To take advantage of the existing 20th harmonic of the variation of x_p due to the long-straight insertion (which does not match x_p) we should place the d quadrupole at a location where the unperturbed x_p is large and the f quadrupole about $\frac{1}{40}$ of the circumference away where x_p is small. Large values of x_p occur in the ministraights following the QF in the 3rd, 8th and 13th

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normal cells after the long-straight cell. (The 3rd normal cell after the long-straight cell is, in fact, the medium-straight cell.) x_p has no large value in the long-straight cell. The large values of x_p at these 3 locations are about the same and we will take the 8th cell as an example. The d quadrupole is then placed in the QF-ministraight in cell 8. Small values of x_p occur in cells 5 and 6 on one side of cell 8 and in cells 10 and 11 on the other side. Again, we will consider only cells 5 and 6. Now, we have two choices

<u>Arrangement A</u>

For no first order change in ν_x and ν_y the f quadrupole should be placed in the QF-ministraight of cell 6 where β_x and β_y have the same values as those at the d quadrupole. We take 1 ft. long quadrupoles placed 1 ft. from the downstream ends of the ministraights. (The drift space between the quadrupole and the B1 magnet is 1 ft. long.) To retain symmetry and to avoid large increases in x_{pmax} and β_{max} we insert a pair of fd quadrupoles in each superperiod. (Altogether 12 quadrupoles.) For various B' in these quadrupoles using SYNCH we obtain the following values at transition.

Table 1. Arrangement A - No reduction in ν
f(QF-mini in cell 6) + d(QF-mini in cell 8)

B' (kG/m)	γ_t	ν_x	ν_y	x_{pmax}(m)	β_{max}(m)
± 0	19.612	20.279	20.317	5.219	123.0
± 2.0	19.542	20.279	20.317	5.283	121.2
± 4.0	19.471	20.278	20.317	5.432	121.3
± 6.0	19.399	20.276	20.317	5.617	123.1
± 8.0	19.326	20.274	20.317	5.866	131.4
±10.0	19.252	20.271	20.317	6.242	142.0
±15.0	19.064	20.262	20.316	7.224	173.5
±20.0	18.869	20.248	20.315	8.269	210.9
±25.0	18.668	20.232	20.314	9.383	253.6
±30.0	18.460	20.212	20.312	10.590	301.1

These low B' values can be provided by air core quadrupoles. As can be seen ν_x and ν_y are essentially unchanged and the increases in β_{max} and x_{pmax} are tolerable.

Arrangement B

We can place the f quadrupole in the QD-ministraight of cell 5 where x_p has the lowest value and where β_x has a value approximately $\frac{1}{4}$ that at the d quadrupole. This arrangement is more efficient for reducing γ_t but will cause a reduction in ν_x and ν_y. Hence the amount of reduction in γ_t attainable is limited by betatron resonances. For the same reduction in γ_t, however, this arrangement gives smaller increases in x_{pmax}

and β_{max} compared to Arrangement A. For various B' values SYNCH runs give at transition:

Table 2. Arrangement B - With reduction in ν
f(QD-mini in cell 5) + d(QF-mini in cell 8)

B'(kG/m)	γ_t	ν_x	ν_y	x_{pmax}(m)	β_{max}(m)
0	19.612	20.279	20.317	5.219	123.0
± 2.0	19.528	20.250	20.288	5.329	125.8
± 4.0	19.440	20.222	20.261	5.443	128.8
± 6.0	19.349	20.195	20.234	5.560	131.9
± 8.0	19.256	20.167	20.208	5.682	135.1
±10.0	19.159	20.141	20.183	5.993	138.3
±15.0	18.904	20.075	20.122	6.853	146.8
±20.0	18.628	20.012	20.065	7.782	165.1
±25.0	18.332	19.949	20.010	8.790	185.2
±30.0	18.014	19.888	19.958	9.890	206.7

Since one runs into the $\nu_x = 20$ resonance at about $\gamma_t = 18.6$, this is the lowest γ_t one can obtain using this Arrangement.

Neither arrangement is effective for increasing γ_t. For this the straightforward arrangement is the best, namely, to place only f quadrupoles at locations where β_x is large and x_p is small. For this arrangement ν_x increases simultaneously with γ_t. The increment in γ_t is, therefore, limited.

To produce a positive γ_t-jump as required for Case 1 of FN-215A one can still use Arrangements A or B. The quadrupoles should be turned on adiabatically well before transition. It may even be possible to have the quadrupoles turned on before injection. The positive γ_t-jump is, then, attained shortly after transition by turning the quadrupoles off.

In general, the most desirable arrangement is one in which γ_t is first reduced by reducing ν to a value close to but still far enough away from a resonance and γ_t is reduced the rest of the way by the action produced in Arrangement A. Such an arrangement should give the lowest x_{pmax} and β_{max}.

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